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# Effect of stride length on overarm throwing delivery: Part II: An angular momentum response ☆

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ABSTRACT

This is the second component of a two-part series investigating 3D momentum profiles specific to overhand throwing, where altering stride reportedly influences throwing mechanics resulting in significantly different physiologic outcomes and linear momentum profiles. Using a randomized cross-over design, nineteen pitchers (15 collegiate and 4 high school) were assigned to pitch two simulated 80-pitch games at ±25% of their desired stride length. An 8-camera motion capture system (240 Hz) integrated with two force plates (960 Hz) and radar gun tracked each overhand throw. Segmental angular momentums were summed yielding throwing arm and total body momentums, from which compensation ratio's (relative contribution between the two) were derived. Pairwise comparisons at hallmark events and phases identified significantly different angular momentum profiles, in particular total body, throwing arm, and momentum compensation ratios ($P \leqslant 0.05$) as a result of manipulating stride length. Sagittal, frontal, and transverse angular momentums were affected by stride length changes. Transverse magnitudes showed greatest effects for total body, throwing arm, and momentum compensation ratios. Since the trunk is the main contributor to linear and angular momentum, longer strides appear to better regulate transverse trunk momentum in double support, whereas shorter strides show increased momentum prior to throwing arm acceleration.



## 1. Introduction

Stride length has been shown to be an important determinant in overhand throwing deliveries (Ramsey, Crotin, & White, 2014), reflecting previous work describing pitching biomechanics from a mound (Lin, Su, Nakamura, & Chao, 2003; Seroyer et al., 2010). Stride length is considered a necessary kinematic trait for (*i*) establishing the timing for kinetic chain events and (*ii*) appropriating mechanical energy from the lower body and transitioning it to the throwing hand (Lin et al., 2003; Seroyer et al., 2010). Temporal parameters such as onset of stride foot contact (SFC) and respective times in single and double support, as characterized as the generation (peak knee height to SFC) and brace-transfer (SFC to maximal external shoulder rota-

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tion) phases, are reportedly most sensitive to stride length (Ramsey et al., 2014). Among skilled pitchers, desired stride lengths generally range between 80% and 85% body height (Elliott, Grove, Gibson, & Thurston, 1986; Escamilla, Fleisig, Barrentine, Zheng, & Andrews, 1998). New evidence suggests stride lengths greater than 75% body height increases physiologic demand, as exemplified by perceived exertion, heart rate, and metabolic responses whereas reducing desired stride may perhaps may mitigate fatigue (Crotin, Kozlowski, Horvath, & Ramsey, 2014).

This is the second article in a two-part series examining three-dimensional momentum profiles specific to overarm throwing mechanics challenged by manipulating stride length. Perhaps altering lower extremity mechanics disrupts intersegmental momentum transfers up the kinetic chain to the detriment of throwing arm kinematics and kinetics (Seroyer et al., 2010; Stodden, Langendorfer, Fleisig, & Andrews, 2006; Werner, Suri, Guido, Meister, & Jones, 2008). The first article of this two-part series suggested linear throwing arm energetics were influenced by stride length, evidenced by the significant change in the relative momentum contribution between the throwing arm and total body during the arm acceleration phase of the delivery cycle (Ramsey et al., 2014). Despite greater physiologic demand with longer stride lengths (Crotin et al., 2014), lower momentum compensation ratios when compared to the shorter strides reduce contribution of throwing arm momentum relative to the total body, which perhaps suggest the longer strides may be beneficial in mitigating throwing arm stress (Ramsey et al., 2014).

To our knowledge the only study to depict angular momentum profiles among baseball pitchers reported the trunk comprised the greatest proportion of angular momentum late in the cocking phase (Lin et al., 2003), although the effect of stride length was not considered in the analysis. In light of this, the emphasis for this second paper was on whether angular momentum changes in overhand throwing as a result from manipulating stride length, as was evident with linear momentum (Ramsey et al., 2014). It was speculated that a change in pitchers' stride length would alter total body and throwing arm angular momentums thereby impacting the relative percent contribution of the throwing arm to total body momentum (defined as momentum compensation ratios "MCR"). Higher sagittal and transverse total body and throwing arm angular momentums were expected with understride, whereas MCR's would be reduced owing to the higher contribution of total body angular momentums. The opposite effect was anticipated with overstride, as exemplified by lower overall total body and throwing arm momentums. As a result of the lower total body angular momentums, MCR's were expected to increase owing to the greater relative throwing arm momentum to total body angular momentum. Frontal plane angular momentums, however, were anticipated to remain unchanged between both stride conditions.

## 2. Methods

### 2.1. Subject recruitment

Through flyers and personal contact, twenty collegiate and highly skilled high school pitchers were recruited from local collegiate and travel baseball programs, where one withdrew owing to conflicts with collegiate baseball obligations. The demographics from the 19 participants are listed in Table 1.

All were competitive for at least five seasons, were uninjured or had fully recovered from previous injury at time of testing, and none experienced throwing arm injury that required surgery. Testing was undertaken indoors in a Biomechanics Laboratory. All participants signed an informed consent. Parental consent was signed and obtained for minors. The research study was approved by the University at Buffalo's Children and Youth Institutional Review Board.

### 2.2. Subject preparation and data collection overview

A blinded randomized crossover design was used to assign pitchers to throw two simulated games, beginning with either (*i)* a 25% increased stride length (OS) or (*ii)* a 25% reduced stride (US) from their desired stride length (DSL). Pitchers were crossed over to the alternate condition after a minimum of 72 h rest had elapsed. Allocation to a stride condition was determined by simple randomization from a random numbers table.

Anthropometric measures of height and weight were first obtained. Sixty-three, retro-reflective markers (19 mm and 25 mm) were then affixed bilaterally over anatomical landmarks to distinguish body segments and joint centers, the details of which are described elsewhere (Crotin et al., 2014). A rigid thermoplastic shell affixed with three non-collinear markers was secured over the sacrum using Velcro and elastic overwrap (SuperWrap$^{TM}$, Fabrifoam, Inc., Exton, PA) around the waist to track pelvic movement. Reflective tape was secured to the baseball to determine the instant of ball release from the throwing hand. Full body segmental motion was tracked and reconstructed in three dimensional space using an 8-camera

**Table 1**
Subject demographics.

| High school | | Collegiate | Age (Yrs) | Height (m) | Mass (kg) |
|---|---|---|---|---|---|
| n | 15 | 5 | 18.63 ± 1.67 | 1.84 ± 0.054 | 82.14 ± 0.054 kg |
| Handed | Left | Right | | | |
| | 4 | 15 | | | |